Suppression of Machining Fluid Misting by Polymer Additives

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Machining Fluids for Metalworking

Function: *Cool and lubricate working surfaces, remove metal chips.*

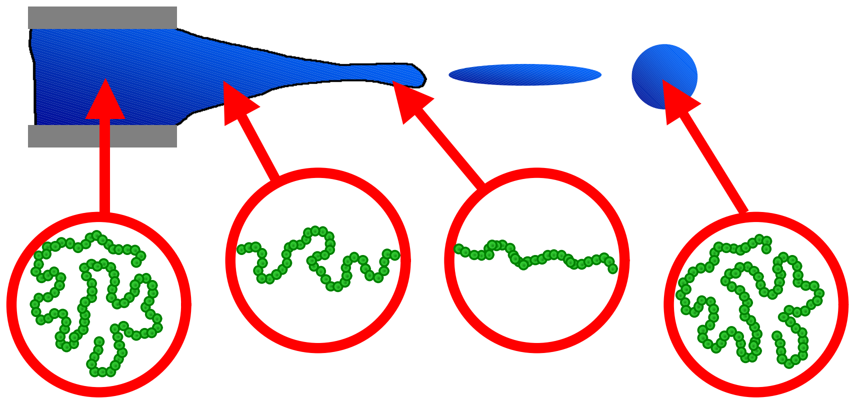
Metalworking Processes: *Milling, gun-drilling, grinding, etc.*

Fluid Types:

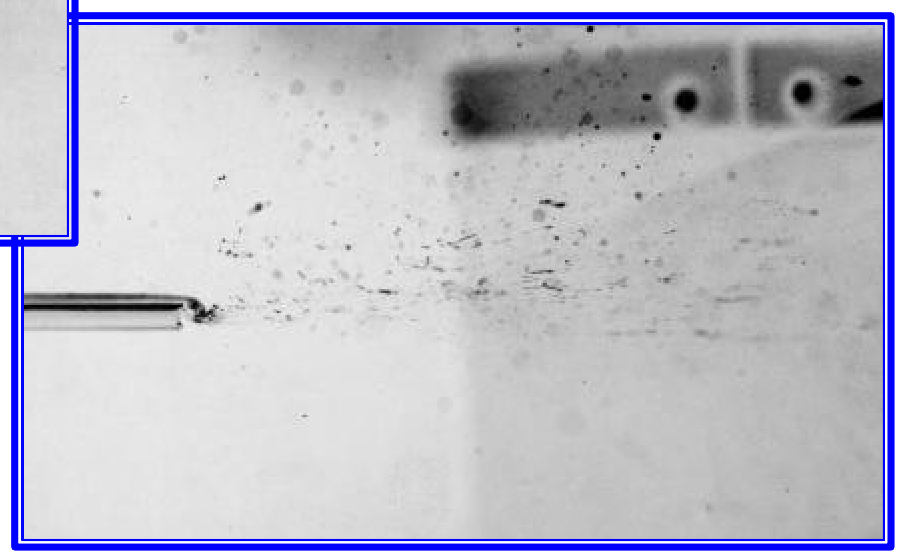
Straight Oil	*light mineral oils (~20 cp)*
Water-Based	*oil-in-water emulsions*

Misting Problem: *Machining fluids break up in high speed machining under impact, shearing, and centrifugal force. Droplets < 5mm are easily entrained in air, leading to worker exposure via inhalation.*

Influence of Polymers on Atomization

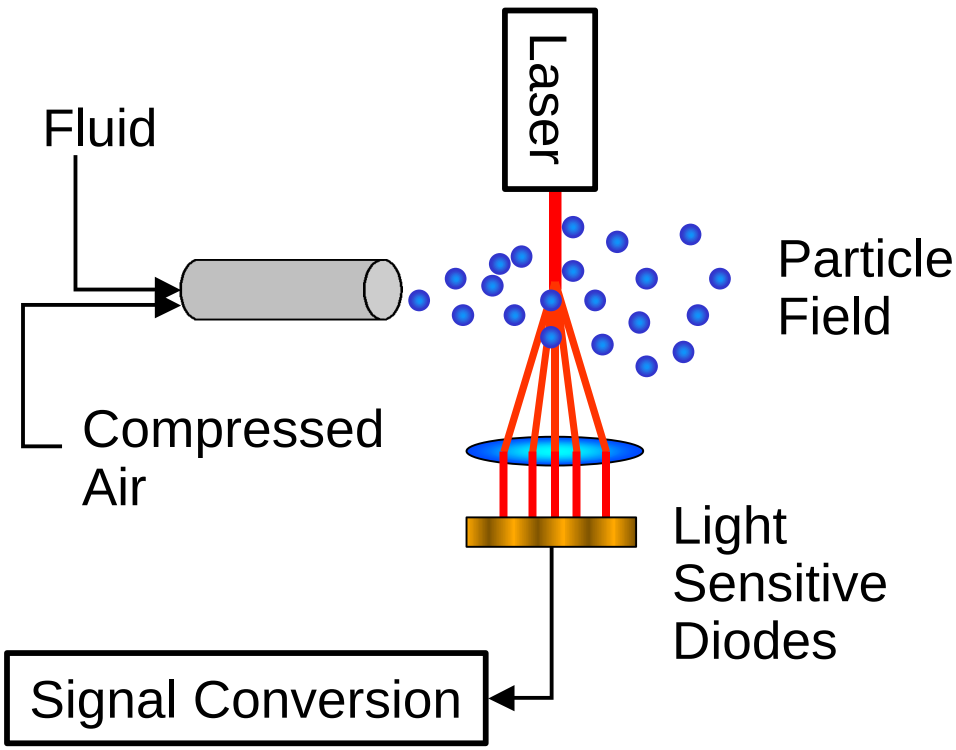


Mineral Oil

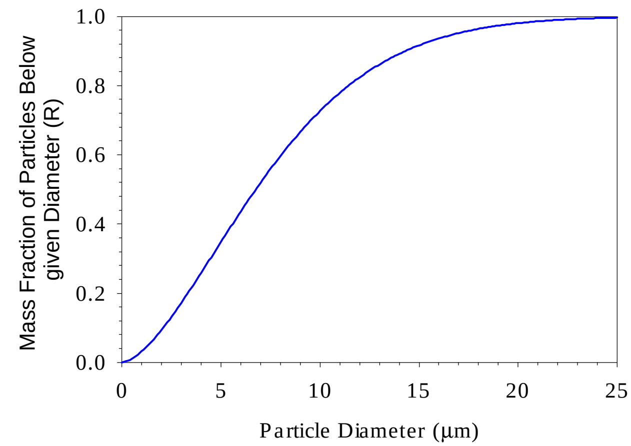


Mineral Oil with 1.0 g/l Polyisobutylene

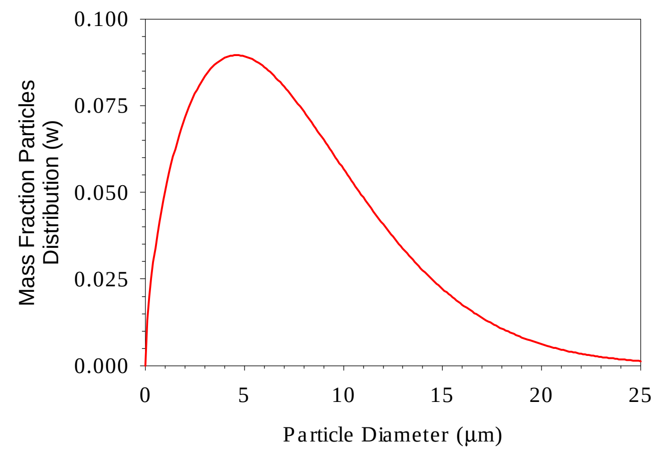
Particle Sizing and Size Distributions



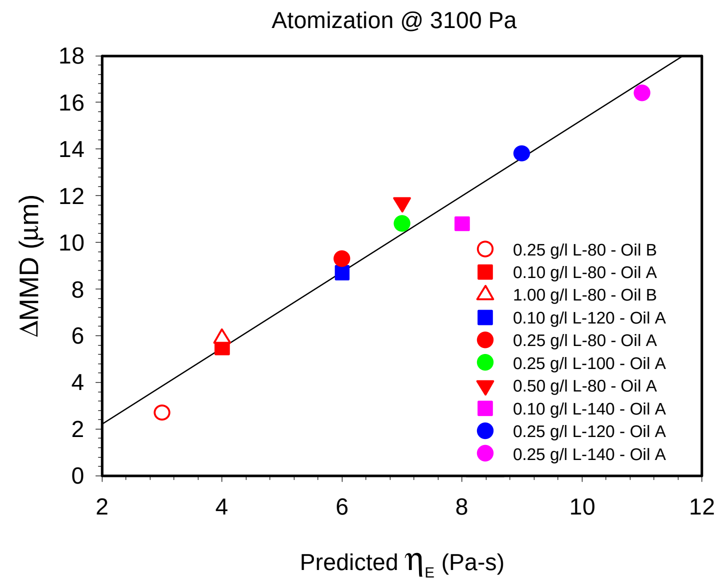
$$R = 1 - \exp\left[-\left(\frac{d}{X}\right)^{N}\right]$$



$$W = \frac{\partial R}{\partial d}$$



Extensional Viscosity Measurements and its Relationship to Atomization

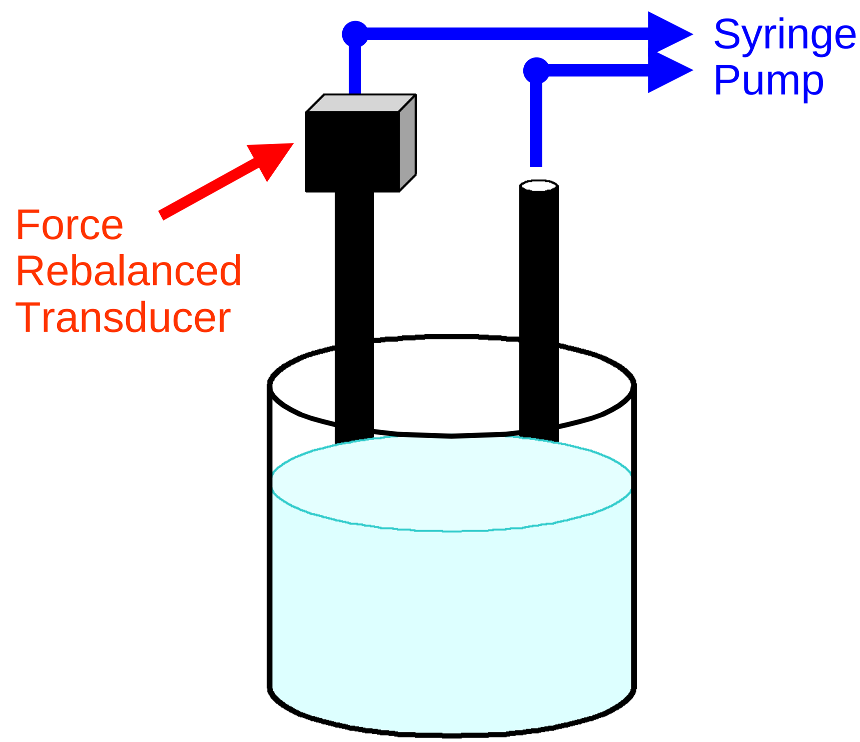


Opposing Jet Rheometer

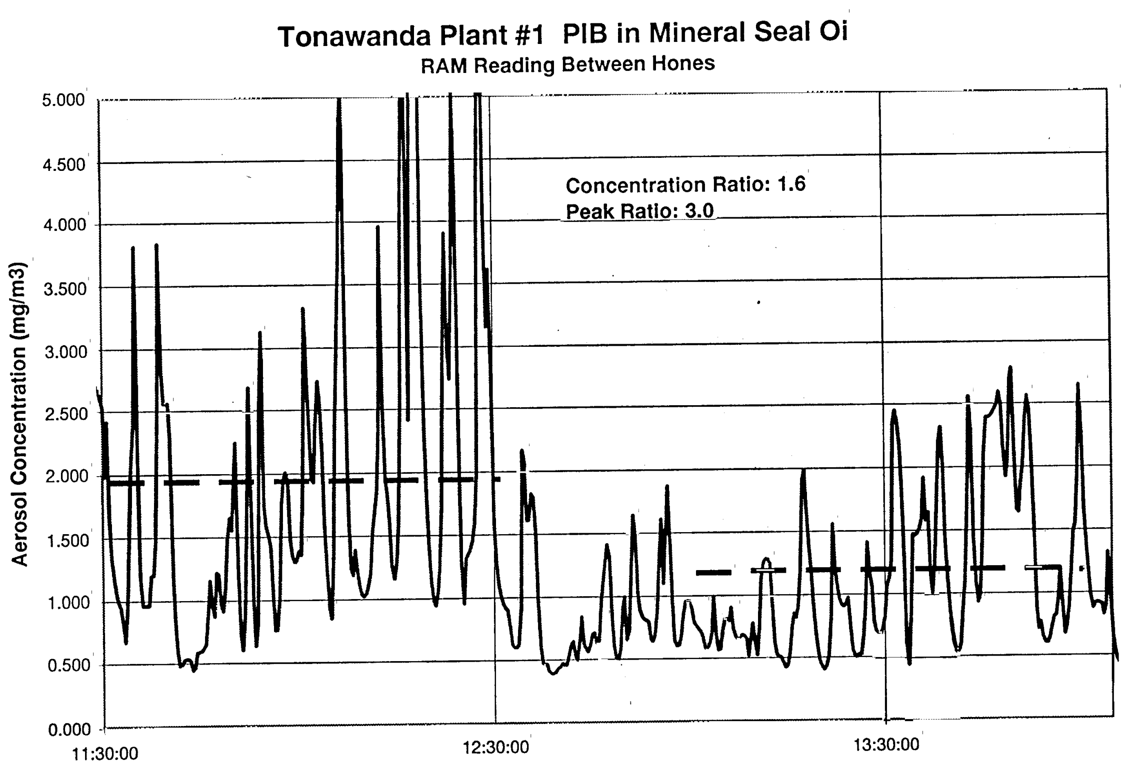
$$Stress = \frac{Measured\ Force}{Nozzle\ Area}$$

$$Strain\ Rate \approx \frac{Flow\ Rate}{Nozzle\ Area \times \frac{1}{2} Gap}$$

$$h_E \approx \frac{Stress}{Strain\ Rate}$$



Oil Mist Suppress using Polyisobutylene in Plant Testing



- ⇨70 ppm of PIB add to machining oil
- ⇨ 40% reduction in average mist levels
- ⇨67% reduction in peek mist levels
- ⇨24 hours plus service life

Use of High-M Polymers for Antimisting Treatment of Machining Fluids in Automotive Industry

<u>Straight Oils</u>

Polymer: 20-50 ppm polyisobutylene ($M= 1\text{-}2x10^6$)
Replenishment schedule: daily-weekly
Status: worldwide implementation by Ford, and others.

<u>Water-based Fluids</u>

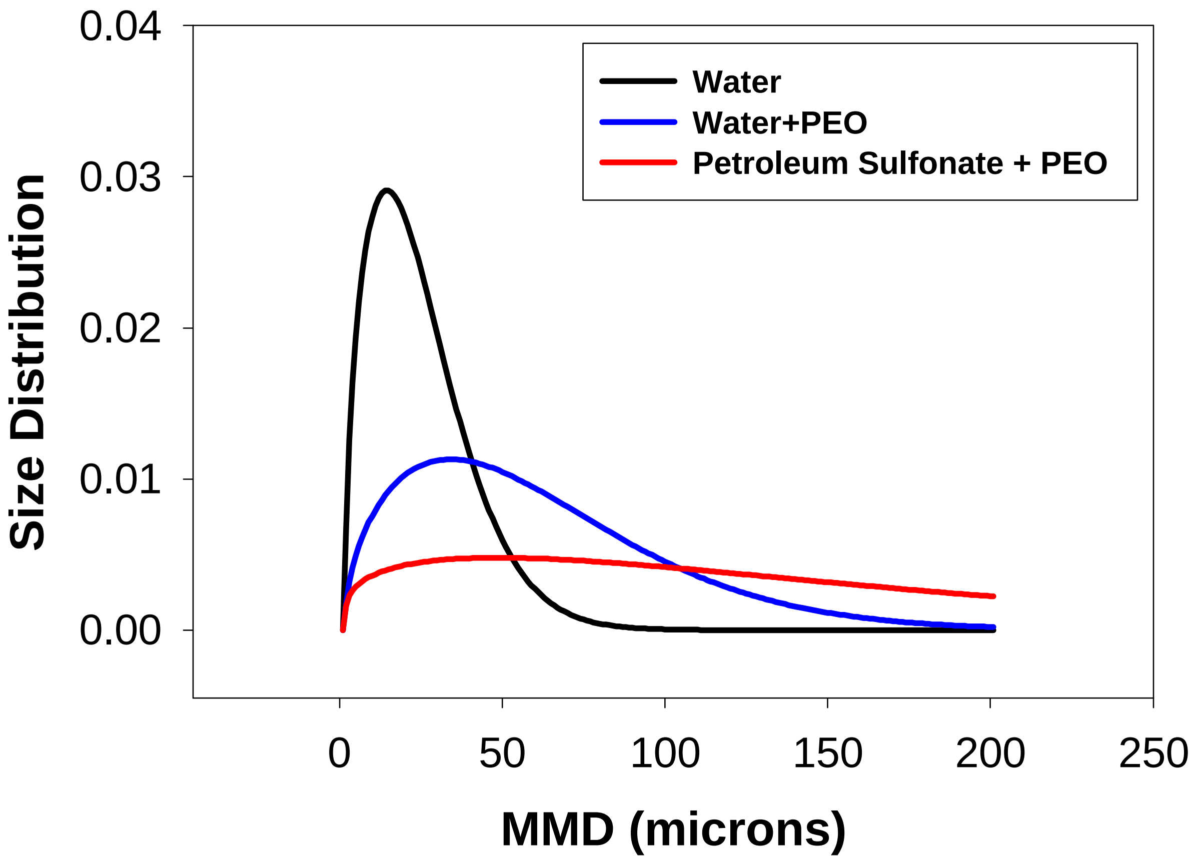
Polymer: up to 500 ppm polyethylene oxide ($M\text{-}1\text{-}2x10^6$)
Replenishment schedule: daily
Status: plant-tested but not widely implemented.

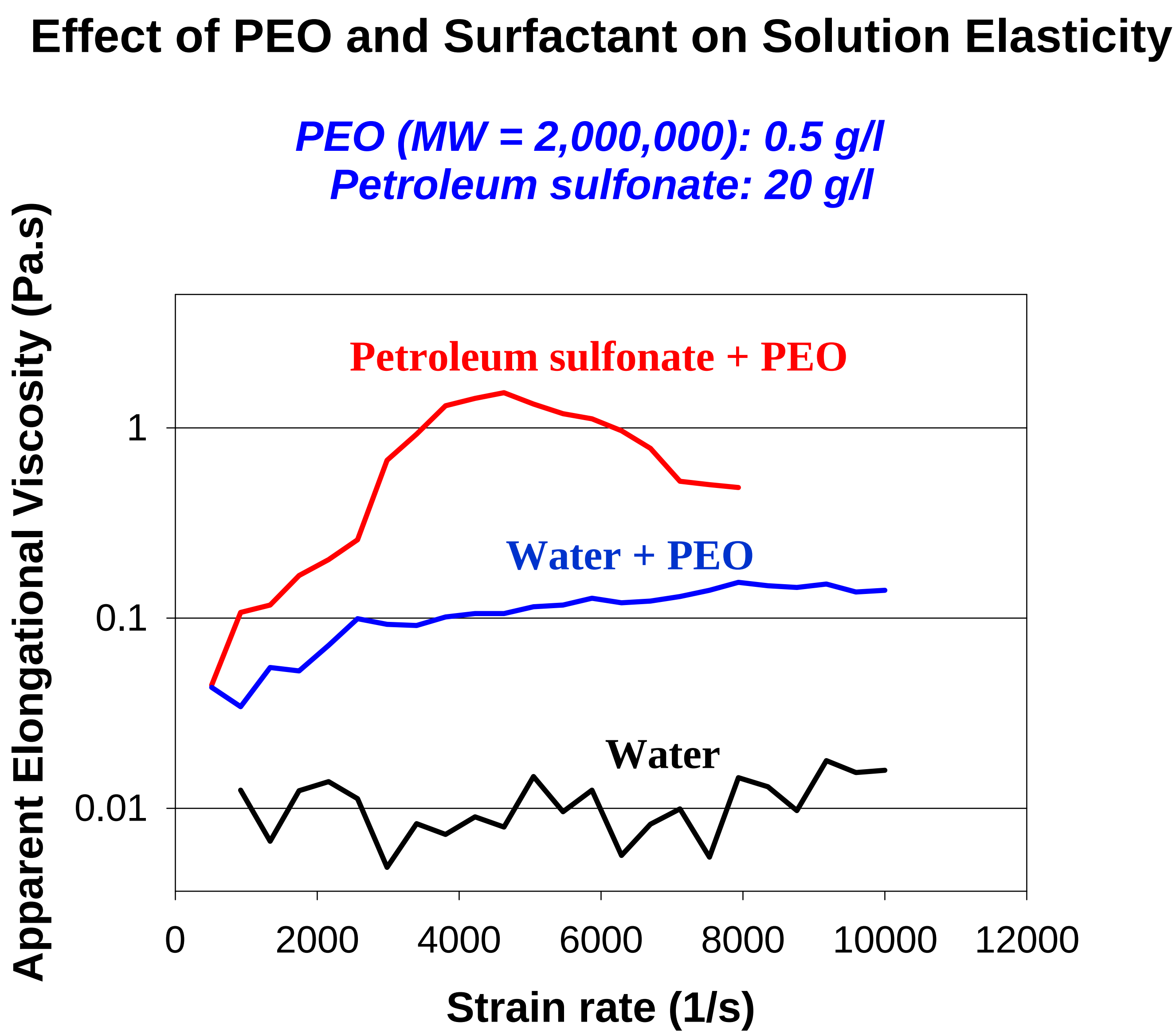
Challenge: ***Improve economics of treatment for water-based fluids by reducing mechanical degradation and/or reducing treatment concentrations.***

Associative Chemistry: ***Polymer-surfactant and polymer-polymer interactions.***

Effect of PEO and Surfactant on Drop Size Distribution

PEO (MW = 2,000,000) : 0.5 g/l
Petroleum sulfonate:20 g/l

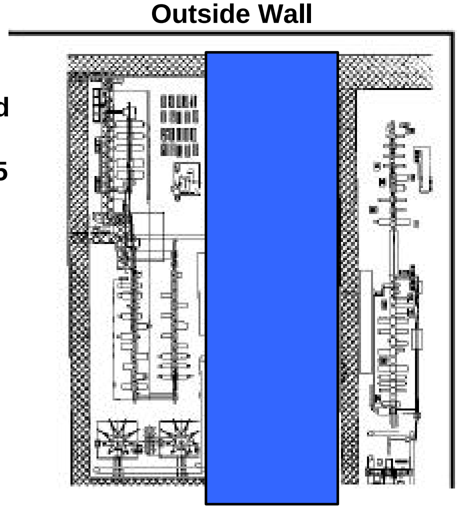



Effect of PEO and Surfactant on Solution Elasticity
PEO (MW = 2,000,000): 0.5 g/l
Petroleum sulfonate: 20 g/l
Petroleum sulfonate + PEO
Water + PEO
Water
1
0.1
0.01
0
2000
4000
6000
8000
10000
12000
Apparent Elongational Viscosity (Pa.s)
Strain rate (1/s)

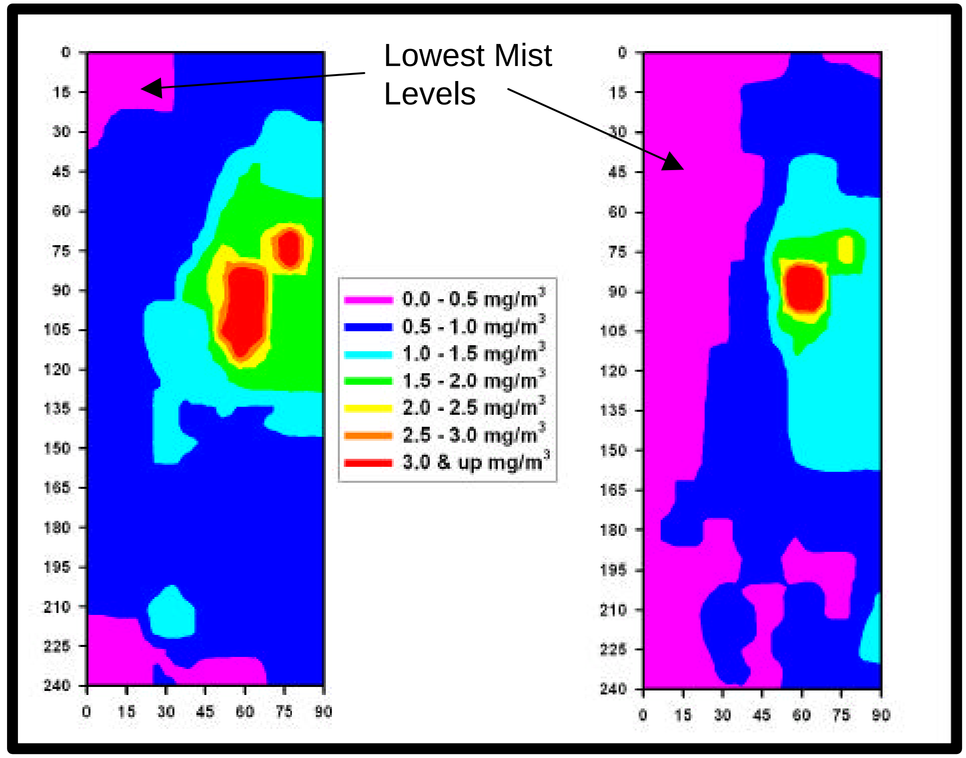
Plant Testing of Polyethylene Oxide as a Mist Suppressant at a Detroit Daimler-Chrysler Facility

Layout of Plant Test

- Aerosol measured by TSI DustTrak and RAM-1 units, at a grid resolution of 15 ft by 15 ft covering an area of 240 ft by 90 ft.
- Two 40,000 gallon soluble oil systems treated with 150 ppm of PEO added as a slurry.



Mist Suppression with PEO



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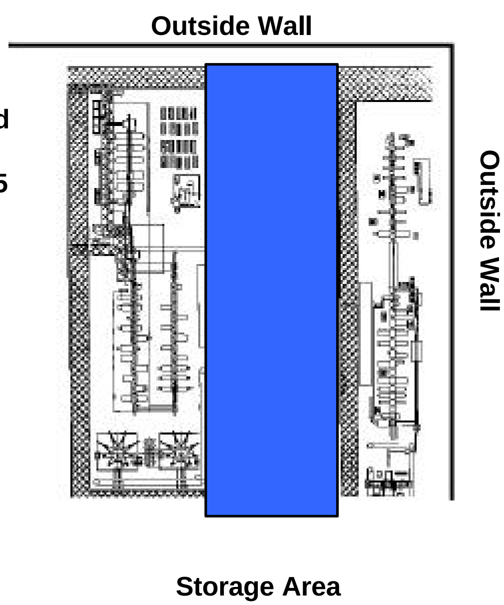


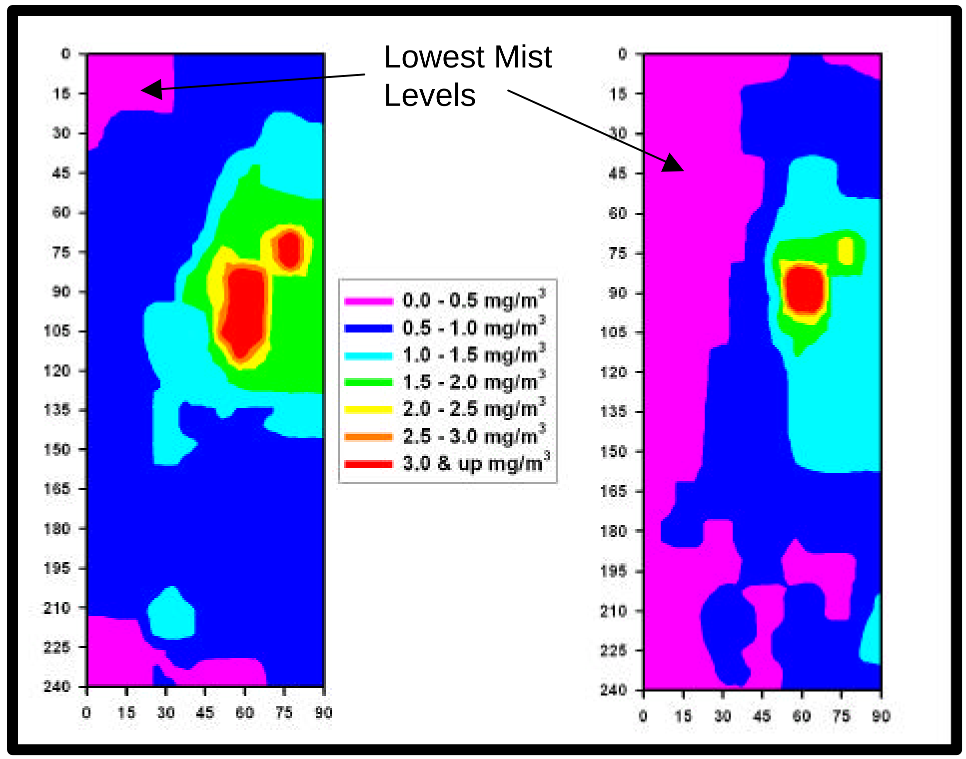
Mist Suppression with PEO

Before

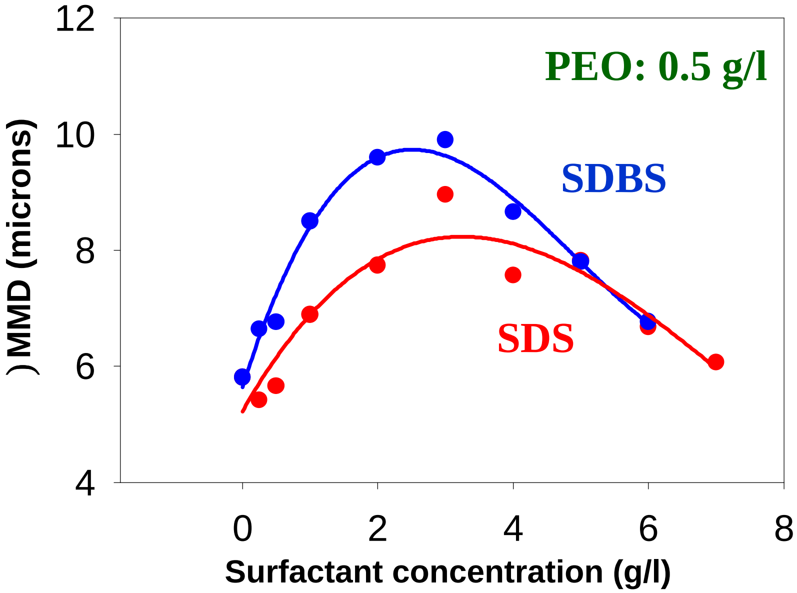
Background Mist Levels

After

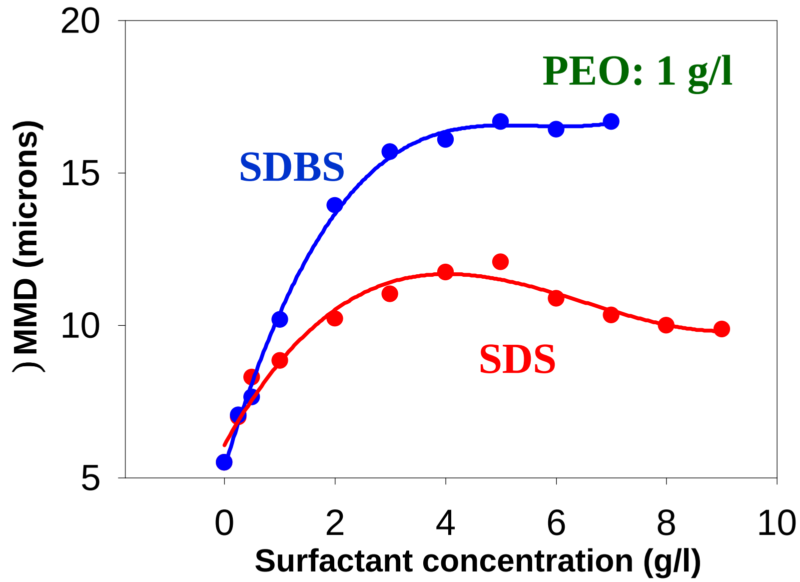
Mist Levels 0.5 hour after PEO Addition



c[η] = 0.25

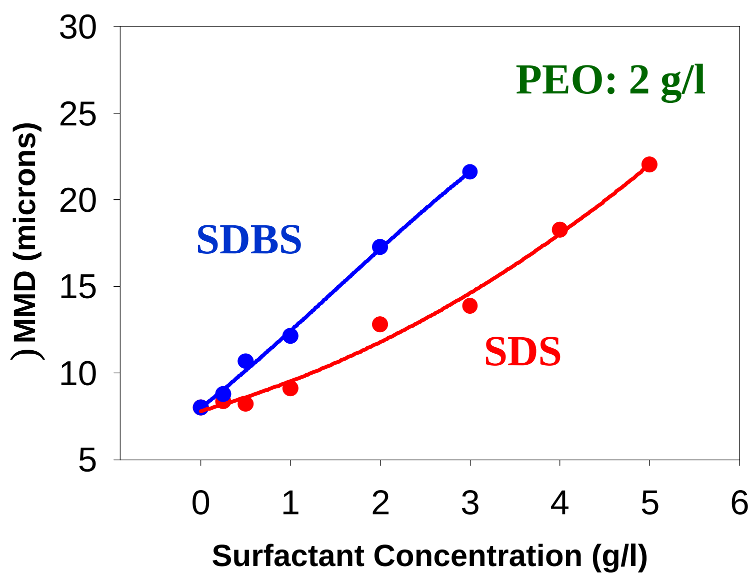


c[η] = 0.5



EFFECT OF PEO CONCENTRATION ON DROP SIZE

c[η] = 1



Conclusions

Polymer additives are very effective in reducing machining fluid mist.

Economic barriers remain for treatment of water-based fluids:

high treatment levels (up to 500 ppm)
mechanical degradation of polymer (daily replenishment)
higher cost of water-soluble polymers

PEO-surfactant interactions greatly improve antimisting effectiveness in laboratory and plant tests - ***reduces treatment to 150 ppm.***

Further improvements are expected through optimization of polymer-surfactant interactions and synthesis of "designer" antimisting systems.